by the processes of mental integration develops in one direction into monotheism, and in the other into pantheism. When the powers of nature are held predominant in the minds of the philosopher through whose cogitations this evolution of theism is carried on, pantheism, as the highest form of psychotheism, is the final result; but when the moral qualities are held in highest regard in the minds of the men in whom this process of evolution is carried on, *monotheism*, or a god whose essential characteristics are moral qualities, is the final product. The monotheistic god is not nature, but presides over and operates through nature.

Psychotheism has long been recognised. All of the earlier literature of mankind treats largely of these gods, for it is an interesting fact that in the history of any civilised people the evolution of psychotheism is approximately synchronous with the invention of an alphabet. In the earliest writings of the Hebrews, the Egyptians, the Hindoos, and the Greeks, this stage is discovered, and Jehovah, Osiris, Indra, and Zeus are characteristic representatives. As psychotheism and written language appear together in the evolution of culture, this stage of theism is, consciously or unconsciously, a part of the theme of all written history.

The palæontologist, in studying the rocks of the hill and the cliffs of the mountain, discovers in inanimate stones the life forms of the ancient earth. The geologist, in the study of the structure of valleys and mountains, discovers groups of facts that lead him to a knowledge of more ancient mountains and valleys and seas, of geographic features long ago buried, and followed by a new land with new mountains and valleys and new seas. The philologist, in studying the earliest writings of a people, not only discovers the thoughts purposely recorded in those writings, but is able to go back in the history of the people many generations, and discover with even greater certainty the thoughts of the more ancient people who made the words.

Thus the writings of the Greeks, the Hindoos, the Egyptians, and the Hebrews, that give an account of their psychic gods, also contain a description of an earlier theism unconsciously recorded by the writers themselves. Psycotheism prevailed when the sentences were coined, physitheism when the words were coined. So the philologist discovers physitheism in all ancient literature. But the verity of that stage of philosophy does not rest alone upon the evidence derived from the study of fossil philosophies through the science of philology. In the folk-lore of every civilised people having a psychotheic philosophy, an earlier philosophy, with nature gods, is discovered.

The different stages of philosophy which I have attempted to characterise have never been found in purity. We always observe different methods of explanation existing side by side, and the type of a philosophy is determined by the prevailing characteristics of its explanations of phenomena. Fragments of earlier are always found side by side with the greater body of the later philosophy. Man has never clothed himself in new garments of wisdom, but has for ever been patching the old, and the old and the new are blended in the same pattern, and thus we have *atavism* in philosophy. So in the study of any philosophy which has reached the psychotheic age, patches of the earlier philosophy are always seen. Ancient nature gods are found to be living and associating with the supreme psychic deities.

Thus in anthropological science there are three ways by which to go back in the history of any civilised people and learn of its barbaric physitheism. But of the verity of the stage we have further evidence. When Christianity was carried north from Central Europe, the champions of the new philosophy, and its consequent religion, discovered, among those who dwelt by the glaciers of the north, a barbaric philosophy which they have preserved to history in the Eddas and Sagas, and Norse literature is full of a philosophy in a transition state, from physitheism to psychotheism; and mark the people discovered in this transition state were inventing an alphabet—they were carving Runes.

Then a pure physitheism was discovered in the Aztec barbarism of Mexico, and elsewhere on the globe many people were found in that stage of culture to which this philosophy properly belongs. Thus the existence of physitheism as a stage of philosophy is abundantly attested. Comparative mythologists are agreed in recognising these two stages. They might not agree to throw all of the higher and later philosophies into one group, as I have done, but all recognise the plane of demarcation between the higher and lower groups as I have drawn it. Scholars, too, have come essentially to an agreement that physitheism is earlier and older than psychotheism.

Perhaps there may be left a "doubting Thomas" who believes that the highest stage of psychotheism—that is, monotheism—was the original basis for the philosophy of the world, and that all other forms are degeneracies from that primitive and perfect state. If there be such a man left, to him what I have to say about philosophy is blasphemy.

Again, all students of comparative philosophy, or comparative mythology, or comparative religion, as you may please to approach this subject from different points of view, recognise that there is something else: that there are philosophies, or mythologies, or religions, not included in the two great groups. All that something has been vaguely called *fetishism*.

I have divided it into two parts—*hecastotheism* and *zootheism*. The verity of zootheism as a stage of philosophy rests on abundant evidence. In psychotheism it appears as *devilism* in obedience to a well-known law of comparative theology, viz., that the gods of a lower and superseded stage of culture ofttimes become the devils of a higher stage.

So in the very highest stage of psychotheism we find beast devils. In Norse mythology we have Fenris, the wolf, and Jormungander, the serpent. Dragons appear in Greek mythology, the bull is an Egyptian god, a serpent is found in Zendavesta; and was there not a scaly fellow in the Garden of Eden? So common are these beast-demons in the higher mythologies that they are used in every literature as rhetorical figures. So we find, as a figure of speech, the great red dragon with seven heads and ten horns, with tail that with one brush sweeps away a third of the stars of heaven. And wherever we find nature worship we find it accompanied with beast worship. In the study of higher philosophies, having learned that lower philosophies often exist side by side with them, we might legitimately conclude that a philosophy based upon animal gods had existed previous to the development of physitheism, and philologic research leads to the same conclusion.

But we are not left to base this conclusion upon an induction only, for in the examination of savage philosophies we actually discover zootheism in all its proportions. Many of the Indians of North America, and many of South America, and many of the tribes of Africa, are found to be zootheists. Their supreme gods are animals—tigers, bears, wolves, serpents, birds. Having discovered this, with a vast accumulation of evidence, we are enabled to carry philosophy back one stage beyond physitheism, and can confidently assert that all the philosophies of civilisation have come up through these three stages.

And yet there are fragments of philosophy discovered which are not zootheistic, physitheistic, nor psychotheistic. What are they? We find running through all three stages of higher philosophy that phenomena are sometimes explained by regarding them as the acts of persons who do not belong to any of the classes of gods found in the higher stages. We find fragments of philosophy everywhere which seem to assume that all inanimate nature is animate; that mountains and hills, and rivers and springs, that trees and grasses, that stones, and all fragments of things are endowed with life, and with will, and act for a purpose. These fragments of philosophy lead to the discovery of hecastotheism.

Philology also leads us back to that state when the animate and inanimate were confounded; for the holophrastic roots into which words are finally resolved show us that all inanimate things were represented in language as actors.

Such is the evidence on which we predicate the existence of hecastotheism as a veritable stage of philosophy. Unlike the three higher stages, it has no people extant on the face of the globe known to be in this stage of culture. The philosophies of many of the lowest tribes of mankind are yet unknown, and hecastotheism may be discovered, but, at the present time we are not warranted in saying that any tribe entertains this philosophy as its highest wisdom.

THE NATURE OF ELECTRICITY[1]

On surveying the wide sea upon which the numerous and varied practical applications of electricity are launched for the subject of this evening's address, I have been puzzled to steer a course that shall avoid the dazzling shoals of theory on the one hand, and the dry hard rocks of practice on the other.

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[1] Abstract of the Inaugural address to the Society of Telegraph Engineers, by Mr. William Henry Preece (President), delivered January 28, 1880. Revised by the Author.

Hypothesis is a veritable Scylla that captivates the imagination and often sends the visionary to destruction, while practice alone is a hard-hearted Charybdis that lures the matter-of-fact practical man to folly and expense. Practice must be tempered with theory to utilize advantageously the great forces of nature, and theory itself must be based on practice, or on facts, to be comprehensive and acceptable. Hence success is the offspring of the marriage of practice and theory, and, therefore, as the two are so intimately connected, I have determined to steer a middle course to-night to survey the progress of each in our profession, and to show their mutual relationship.

What is theory? It is an explanation of the hidden cause of certain effects that are evident to the senses. It is an effort of the imagination to account for operations that are in themselves invisible and insensible, but which result in facts that are observable and known. Thus the movements of all those bright bodies by which

> "the floor of heaven
> Is thick inlaid with patines of bright gold,"

are explained by the theory of gravity. Their appearance, vagaries, and beauties are accounted for by the undulatory theory of light. The warmth that the monarch of them all shed upon this earth countless ages ago, and that is now restored to us in our household fires, is explicable on the molecular theory of heat. The constitution of matter and its various states of solid, liquid, and gas, are completely explained by the atomic theory of Democritus and Dalton, and the modern kinetic theory of gases.

It is impossible for a practical man who has devoted more than a quarter of a century to the application of electricity to useful purposes, to avoid devoting much contemplation to the nature of the agent which he has to make use of. Is there a member of this society who has not striven to peer into the region of the unknown, who has not speculated on the power he uses, or who has not formed some conception in his mind of the nature of electricity? Yet it is remarkable that the answer to the question, What is electricity? cannot even now be given with authority. Faraday, our great apostle, whose researches should be every electrician's bible, declined to venture an answer, nor did he ever directly formulate his ideas on the subject, though his publications indicate pretty clearly and with no uncertain sound what they were. Clerk-Maxwell, who, while he overthrew all existing theories, failed to supply their place before he was so untimely removed from us. Sir William Thomson, in his published papers, always carefully eschews the consideration of any physical theory of electricity. The French electricians simply use the one-fluid theory as a convenience of language, while the Germans, as a rule, employ the two-fluid theory merely for mathematical purposes. Hence there is no recognised theory of electricity. Some maintain with Du Fay or with Franklin, that it is a form of matter—a substance; others, following Faraday and Grove, consider it a form of force—a motion—like heat and light. It must be either one or the other. There is no other category in which to class it. If it is not a form of matter it must be a form of force. The question I propose to discuss is, therefore, Is electricity a form of matter, or is it a form of force?

In discussing such a vexed question it is necessary to be very precise in language to avoid any misconception of my meaning, therefore I will define both matter and force in the sense in which I use those terms. *Matter* is that which can be perceived by the senses, or can be acted upon by force. It is characterised by weight, inertia, and elasticity. *Force* is that which produces, or tends to produce, the motion of matter. It may be pressure, tension, attraction, repulsion, or anything capable of causing alteration in the natural state of rest or of existing motion of matter.

Matter is found in either the solid, liquid, gaseous, or ultra-gaseous state, and it occupies space. It consists of molecules and atoms. The *atom* is the smallest indivisible part of an element, and a group of atoms of the same or of different elements forms the *molecule*, which has a definite magnitude and is unalterable in form for each substance. The *mass* of a substance is the aggregate of the molecules of which it is composed. There is no generation or destruction of atoms. The indestructibility of matter is a fixed law in nature. The size of the molecule is approximately known. Sir William Thomson says:—"If we conceive a sphere of water as large as a pea to be magnified to the size of the earth, each molecule being magnified to the same extent, the magnified structure would be coarser-grained than a heap of small lead shot, but less coarse-grained than a heap of cricket balls." Fifty million molecules ranged in single file would occupy an inch. They are highly elastic, and unless interfered with would move with constant velocity in straight lines. When they can move about freely without interfering with each other's proceedings, we have the ultra-gaseous state of Crookes, a state found only in very high vacua and under certain adventitious circumstances. When they collide and impinge on each other according to the law of the impact of elastic bodies, interfering with each other's path, we have *gases* as we know them; when their mean free path is so reduced as to bring them within the sphere of mutual attraction, without too narrowly restricting their play, we have *liquids;* when the attraction becomes cohesion and the motion of the molecule is confined to its own sphere, we have *solids.* The number of molecules in a given volume of gas is known, and their velocity calculated. In hydrogen the velocity at 0° Cent. is 6,097 feet per second, the number being 10^{23} per cubic inch. The mean free path of a molecule in air at ordinary pressures is the ten-thousandth part of a millimetre. Besides their constant motion in straight lines the molecules may be set in vibration, rotation, or any other kind of relative motion whatever.

This is the atomic theory of matter born in the brain of Democritus, "the laughing philosopher," 2,300 years ago; preached by Epicurus in Athens, and taught by Lucretius in Rome before the Christian era; lying dormant for eighteen centuries, until it was formulated by Dalton in the last century, and removed from the region of pure speculation by Joule, Clausius, Clerk-Maxwell, and Crookes during our days.

The definition of force shows us that whatever changes or tends to change the motion of matter (or of the molecules of which it is composed), by altering either its direction or its magnitude, is a form of force. Thus gravity is a form of force, for it attracts all matter to the centre of the earth, and it is measured by the rate per second at which a body acquires a velocity in this direction when falling freely at a given spot. Heat is a form of force, for it throws the molecules of matter into violent vibration, or it increases the velocity of their motion in straight lines, which thus becomes the measure of its heat or its *temperature.* Light is a form of force, for it is produced by the undulation of the molecules of matter, and it is transmitted by the undulations of that medium called Ether, which fills all space.

When we take a given free mass and impress upon it a given force, we throw that mass into motion; for instance, when we fire a loaded cannon, we have imparted to the ball "*energy,*" and in virtue of the motion of the ball, this energy is called "*kinetic.*" Again, if we lift the ball to a certain height above the earth's surface—say to the top of a tower—and let it remain there, we have again imparted to it "energy," but this time it is called "*potential,*" for it is dormant or resting. In each case the energy possessed by the ball is the exact equivalent of the work done upon it, that is, of the force impressed and the distance through which it has acted. The motion of the ball is readily transferred to the motion of the individual molecules of the ball. When, in the first case adduced, the ball strikes the side of a ship or a target, its kinetic energy is thus converted into light and heat, which is molecular motion; or, in the second case, when it is allowed to fall, its potential energy is converted into kinetic energy, which again, on coming in contact with the ground, is converted into molecular motion or heat. Energy is always either potential or kinetic, and one of the most remarkable generalisations of modern days is the grand principle of the conservation of energy, which implies that the total energy of the universe is a quantity which can neither be increased nor diminished, though it may be transformed into any of the forms of which energy is susceptible. Energy is therefore as indestructible as matter. All the recent advances in the science of heat have been due to the discovery of this principle, and its application to electricity has gone far to remove that science from the hypothetical state in which it has existed so long.

My purpose is to contend that electricity is not a form of matter but a form of force, and that all its effects are evident to us in one or other of the several forms of energy characterised by the motions of molecules or of mass.

It is interesting to trace the historical growth of theories. The uncultivated human intellect cannot soar above its own limited sphere of childish observation. Whatever is mysterious and incomprehensible in nature is attributed to that which is equally mysterious and incomprehensible. Life has ever been of this character, and heat, magnetism, electricity, and many other unaccountable physical phenomena, have each in their turn been supposed to be causes of life. Even now there are those who would attribute exceptional and peculiar phenomena to spiritual agencies.

Heat was thought by the Greeks to be an animal that bit. It was then for many centuries thought to be a fluid which, entering into bodies, like mercury, made them swell, and this idea existed until this generation, when Rumford showed it to be a kind of motion, and Joule made it a quantitative form of energy.

Thales of Miletus thought that the magnet was endowed with a sort of immaterial spirit, and to possess a species of animation. The Greeks knew also that rubbed amber attracted bits of straw, and supposed it to be endowed with life. Even Boyle, as late as 1675, imagined it to emit a sort of glutinous effluvium which laid hold of small bodies and pulled them towards the excited body. Du Fay in 1733 conceived the double fluid theory, and Franklin in 1747 invented the single fluid theory. Cavendish in 1771 supplied some of the deficiencies of Franklin's theory, but it was Faraday who first exploded the fluid notion and originated the molecular theory of electricity, while Grove boldly classed electricity with light and heat as correlated forces and mere modes of motion.

Light was thought by the Platonists to be the consequence of something emitted from the eye meeting with certain emanations from the surface of things, but no theory of light properly so-called was attempted until Newton produced his celebrated corpuscular theory in 1670, which has lasted until the present day. Even as late as 1816 Faraday himself said—"The conclusion that is now generally received appears to be, that light consists of minute atoms of matter of an octahedral form, possessing polarity, and varying in size or in velocity."[1] Although Huyghens in Newton's own time conceived the undulatory theory, the superior authority of the great English philosopher overshadowed the lesser light, and it was not until Young and Fresnel at the commencement of this century took the matter up, that the present theory of light took firm root.

Thus we see that all these sciences have passed through the same stages of mystery and fancy, and it is only within the present generation that they have emerged from the mythical to the natural, from mere hypothesis to true theory. *Hypothesis* is an imaginary explanation of the cause of certain phenomena which remains to be shown probable or to be proved true. *Theory* is this supposition when it has been shown to be highly probable and all known facts are in agreement with its truth.

A theory, therefore, to be valid and true, must agree with every observed fact; it must not conflict with natural laws; it must suggest new experience, and it should lead to further developments. A theory is absurd if it supposes an agent to act in a manner unknown in all other cases. The fluid theories of electricity are merely descriptive, they do not agree with every observed fact; they have never prompted the invention of a single new experiment, or led to any development. They suppose an agent unknown in other cases and opposed to natural laws. Incomplete theories die a natural death: thus Descartes' vortices, Newton's corpuscular theory of light, the fluid theory of heat, Stahl's phlogiston, Nature abhorring a vacuum, have all disappeared, while complete theories, such as that of gravity, the laws of motion, the conservation of energy, the undulatory theory of light, not only remain, but suggest new fields of inquiry, open out fresh pastures, carry truth and conviction with them, and have led to the most wonderful predictions. The fluid theories of electricity are certainly incomplete, and they deserve a speedy interment. We have to assume the existence of two substances of opposite qualities which mutually annihilate each other on combination—a self-evident absurdity, for the conception of matter involves indestructibility. Franklin imagined his one fluid to be an element of glass; remove electricity, and glass would lose its virtues and properties, and thus glass was to give out its electricity for ever and a day, without loss of weight or sensible diminution. It was to be devoid of dimensions, inertia, weight, and elasticity, and is therefore outside the pale of our definition.

Electricity is therefore not a form of matter. Hence, according to our reasoning, it must be a form of force.

But can we not prove that it is a form of force? Certainly.

Let us first argue from analogy. We know that sound, heat, and light are modes of motion; in what respects does electricity agree with these forms of force?

The fundamental law of electrostatics is that two bodies charged with opposite electricities attract each other with a force dependent on the square of the distance separating them. Whatever influence or power spreads from a point and expands uniformly through space varies in intensity as the square of the distance for the area over which it is spread increases as the square of the radius. This is the case with gravity, light, sound, and heat, which are known forms of force. It is also the case with electricity and magnetism, which ought therefore to be similar forms of force.

If we regard the velocity of transmission of certain electrical disturbances through space, we have every reason to believe that it is the same as that of radiant heat and light. In 1859 two observers in different parts of the country (Messrs. Carrington and Hodgson) saw simultaneously a bright spot break out on the face of the sun, whose duration was only five minutes. Exactly at this time the magnetic needles at Kew were jerked, and the telegraph wires all over the world were disturbed. Telegraphists were shocked, and an apparatus in Norway was set on fire. Auroras followed, and all the effects of powerful magnetic storms. Moreover, the periods of sun-spots, earth currents, and magnetic storms follow the same cycle of about eleven years. Dr. Hopkinson has shown that this electric disturbance through space is as mechanical as its action through short distances, and is therefore identical with the ordinary strains of elastic matter subject to distortion by mechanical force. But Clerk-Maxwell has gone beyond this, and has shown that the velocity of light is identical with that of the propagation of electrical disturbances through space as well as through air and other transparent media. Hence, as light is admitted to be a mode of motion identical with radiant heat, electricity must be of the same category.

There is such a remarkable analogy between the conductivity of the different metals for heat and for electricity—indeed, there is every reason to believe that if the metals were pure, the order and ratio of conductivity would be identical—that it is impossible to resist the conclusion that the mode of transmission in each case is the same. Mr. Chandler Roberts, who, using Prof. Hughes' beautiful induction-balance, showed, by experiments on a comprehensive series of alloys, that the curves indicating the induction-balance effect closely resemble their curves of electrical resistance. He was also able to demonstrate that the induction-balance curve of the copper-tin alloys is almost identical with the curve of the conductivity of heat:—a conclusion of much interest; and he pointed out that we might look with confidence to being able to ascertain, by the aid of the induction-balance, whether the relation between the conductivity of heat and electricity is really as simple as it has hitherto been supposed to be. Moreover, when a wire conveys a current of electricity it is warmed, as the strength of current is increased it is heated and eventually rendered incandescent. The ultimate form which every electric current takes is heat. The wire of every telegraph is warmed in proportion to the currents it transmits. Joule showed that when this heat is produced by a current generated in a battery by chemical force, its amount is exactly equivalent to that which would have been evolved by the direct combination of the atoms. The conducting power of all bodies is affected by heat, and some even, like selenium, by light. Hence, as we know that in the case of heat and light conduction is molecular vibration, we reasonably conclude that it is the same with electricity. In fact, it is impossible to account for these phenomena except on the assumption of the motion of the molecules.

The magnificent researches of Dr. Warren de la Rue and Dr. Hugo Müller on the electric discharge with the 11,000 cells of chloride of silvery battery that the former philosopher has provided himself with in his celebrated laboratory, have shown indisputably that the discharge in air or in gases under various pressures is a function of the molecules filling the space through which the discharge occurs. In fact, the resistance of the discharge between parallel flat surfaces is as the number of molecules intervening between them; and they show that during electrical discharge in a gas there is a sudden and considerable pressure produced by a projection of the molecules against the sides of the containing vessel distinct from that caused by heat, and unquestionably due to the molecular action of electrification. The long continued and patient researches which these eminent physicists are carrying out prove beyond doubt that electrical discharge is simply molecular disturbance. In reality, the fact that no discharge occurs through a perfect vacuum is a crucial proof of the molecular theory.

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[1] "Life," vol. i. p. 216.

Some recent very remarkable researches of M. Plante with his rheostatic machine have shown that fine wires conveying powerful currents are wrinkled up into well-defined regular nodes, that these effects are accompanied by a peculiar crackling, and that the wire itself becomes brittle, giving clear indication of the vibratory motion of the molecules. He gives as the result of his inquiry that electrical transmission is the result of a series of very rapid vibration of the more or less elastic matter which it traverses, and he points out certain analogies between electric motion and sonorous vibrations. This view is supported by the researches of Professors Ayrton and Perry[2] on the viscosity of dielectrics.

Prof. Challis, of Cambridge, has extended this view so far as to embrace magnetism, electricity, light, heat, and gravity in one category of physical force, and to assert that they all result from motions and pressures of a uniform elastic fluid medium pervading all space not occupied by atoms. His views, however, have not received much attention, for they are not based on the foundation of any new facts, and they are utterly subversive of many cherished principles deeply rooted in the scientific mind. It is to be observed, however, that he regards electricity as a form of force.

Mr. Crookes, in his recent beautiful experimental researches into molecular physics in high vacua, has still more conclusively proved the connection that exists between electrical action and molecular motion. In fact, his experiments are so brilliant, his expositions so lucid, that one can fancy one sees with the eye of the body that peculiar play of the molecules which can be evident only to the eye of the mind. Not only has Mr. Crookes established as a physical fact the kinetic theory of gases and the molecular constitution of matter, but he has indicated the existence of a fourth state of matter where the molecules fly about without mutual let or hindrance. He has also led us to doubt the truth of the generally received opinion that an electric current flows from the positive to the negative electrode. It would appear from his investigations that the reverse is the case. Be that as it may, he has added one story to the structure of the molecular theory of electricity.

The criterion of a good theory is, however, its power of prediction. A false theory has never led to prevision. Neither the corpuscular theory of light, nor the fluid theories of heat and electricity, ever led to the prediction of something of which eyes had not seen nor ears heard. The triumphs of prediction in astronomy, sound, light, and heat are innumerable. Faraday predicted the effect of induction in lowering the velocity of currents of electricity and the action of magnetism on a ray of light. Sir William Thomson predicted that a current in passing from a hot to a cold part of a copper bar would heat the point of contact, while in an iron bar it cools it. Peltier predicted the cooling effect of currents on the junctions of thermoelectric pairs.

But the true identity of these physical effects is conclusively shown by their quantitative character and by their adhesion to the law of the conservation of energy. Take the case of the electric light: the consumption of coal in a furnace generates steam, the steam works an engine, the engine rotates a coil of wire in a magnetic field, the motion of the coil in this field induces currents of electricity in the wire, these currents of electricity produce an arc, and thereby heat and light. The energy of the coal is transformed into heat and light through the intermediate agency of electricity. Is it possible to conceive that this intermediate agency is anything but a form of energy? Take the case of the Bell telephone: the energy of the voice produces the energy of sonorous vibration in the air, the vibrations of the air cause the vibrations of the iron disk, the vibrations of the disk vary the magnetism of the magnetic field, this produces currents of electricity in a small coil in this field which vary the magnetism of the distant magnet, which in its turn throws its disk armature into vibration, and thereby repeats at the distant station the sonorous vibrations of the air, and thus reproduces the energy of the voice. A tuning fork comes to rest sooner in front of a telephone than when it is allowed to vibrate freely in air. Here we have the energy of the fork passing through the several stages indicated above, and ultimately coming out in its original form. The energy of sonorous vibrations at the distant station is that lost by the vibrating tuning fork.

Is it possible to assume that in this cycle of changes energy has been transformed into matter and matter again formed into energy? It is impossible and absurd. Clerk-Maxwell said—"When the appearance of one thing is strictly connected with the disappearance of another, so that the amount which exists of the one thing depends on and can be calculated from the amount of the other which has disappeared, we conclude that the one has been formed at the expense of the other, and that they are both forms of the same thing."

Would it be possible to light the streets of New York by the energy of the falling water at Niagara, as has been suggested by our Past President, Dr. Siemens, if the cycle of changes from the one spot to the other were not all different forms of this same energy? Would it be possible to plough a field a mile away from the source of motive power of the transmitting medium if the electric currents were not forms of the same power? Electricity in its effects is and must be a form of energy.

The final stage into which any physical theory grows is that in which every action can be expressed in mathematical language, where every phenomenon is calculated upon an absolute physical basis, and where we can foretell exactly what will occur under any possible emergency. This is the present condition of the science of electricity. We can calculate exactly how much steam power is required to generate a given current to produce a given light. We can tell precisely what dimensions of cable are necessary to give a certain number of words per minute on the other side of the globe. If a fault develop itself in a long cable through the gastronomic propensities of a thoughtless young teredo, we can calculate to within a few fathoms the locality of his edacious depredation.

Clerk-Maxwell, in his classical work on electricity, has used a somewhat curious argument to show that electricity is not, like heat, a form of energy. He says that energy is produced by the multiplication of "electricity" and "potential," and that it is impossible that electricity and energy should be quantities of the same category, for electricity is only one of the factors of energy, the other factor being "potential." But this does not militate in any way against the force of the argument, for in nature we can no more do so than we can separate heat and temperature. Energy usually appears as the product of two factors, and it is the equivalent of the work done. Thus, *Potential energy* is the product of mass and gravitation acting through a distance. *Kinetic energy* is the product of mass and the half-square of velocity. The energy of fluids is the product of volume and pressure. The energy of heat is made up of heat and temperature, and the energy of electricity is the product of electricity and potential. Hence it is that electricity, *per se*, may be said to be a form of force, while all its effects as known to us are forms of energy. Force alone cannot produce energy; it must be force and something else. Force is the power of producing energy, and it must have something on which to produce it. Hence matter is always present; and thus, though heat, light, and electricity are forms of motion, they are in reality properties of matter from which they are inseparable. They are evident to us through the play of the molecules of matter, and thus are properly called molecular forces.

Earth currents have been a favourite subject of inquiry of mine for many years. I have always entertained the idea that they are directly due to the action of the sun. Some disturbance in the sun causes, by induction, a variation in the distribution of the lines of potential on the earth's surface, and produces the conditions required for these currents. I have many facts to support this hypothesis, but I want more to confirm it. Profs. Ayrton and Perry have developed a theory of terrestrial magnetism based on the assumption that the earth is a highly electrified sphere, which not only coincides well with facts, but which tends greatly to support my views. I want observers to record the times of daily maxima and minima. I want them especially to note during those periods of unusual disturbance the direction of the circuits which are *not* affected, for they would give the direction of the lines of equi-potential. This not only offers a useful field of observation, but its failure or success will illustrate the modern method of scientific research, when the brain suggests to the hand and the eye what they have to do, and what they have to look for.

Mr. Preece then went on to speak of the educational work of the Society and to notice some of the recent practical applications of electricity, and in speaking of the telephone stated that litigation has commenced between the Post-Office and the telephone companies not to restrict or in any way to interfere with the use of the telephone, but to prevent the establishment of a

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[1] *Comptes Rendus*, lxxxix., pp. 76–80, 1879.

[2] *Proc.* Roy. Soc. pp. 7–8, 1878.

[1] Vol. i., p. 30.

particular branch of post-office telegraph business with its licence or consent.

Mr. Preece in conclusion congratulated the Society on its great success.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE

CAMBRIDGE.—The Cambridge mathematical tripos this year contains 102 names. There are 33 classed as wranglers, 33 as senior optimes, 33 as junior optimes, and 3 ægrotant. In 1879 the list contained 91 names: 28 wranglers, 33 senior optimes, 29 junior optimes, and 1 ægrotat. The senior wrangler, Mr. Joseph Larmor, of St. John's, is a native of Belfast, and was born in 1857. He was educated at the Royal Academical Institution and Queen's College, Belfast. In 1874 he graduated at the Queen's University, Belfast, obtaining a double first in mathematical and experimental sciences, with two gold medals and exhibitions. He obtained similar distinction when he became M.A. In 1876 he entered the University of London, where he obtained an exhibition for mathematics, subsequently being awarded the Arnott exhibition and medal in experimental physics. At the first B.A. examination in 1878 he obtained the University scholarship in mathematics. He subsequently proceeded to the degree of B.Sc. In 1876 he obtained an open scholarship at St. John's, and has been on several occasions a prizeman at the college examinations. The next in order are Mr. Joseph John Thomson, of Trinity College; Mr. Walter Burt Allcock, a scholar of Emmanuel; and Mr. Homersham Cox, of Trinity. It is remarkable that the senior wranglers of two successive years have been from Queen's College, Belfast.

Among the wranglers this year, if the list had been complete, Miss Scott of Girton College would have been bracketed eighth wrangler. Moreover, she is younger than many of the wranglers, being still under twenty-two. Possibly she may go in for the Smith's Prize examination, although in the present state of regulations it would be impossible to award it to a lady. Nevertheless this achievement must be one more blow to those who would persistently keep ladies from having Cambridge degrees. Miss Scott intends to proceed to a degree at London University in physics. The fourth place in the first class of the recent moral sciences tripos was secured by Miss Martin of Newnham; and it is said that the only names in the first class in the historical tripos were those of two lady students, also of Newnham. No men were placed in the first class in this tripos.

Prof. Stuart reopens his workshop at Cambridge this term, and there will be practical instruction in the use of tools in iron and wood which will be provided, and also more advanced classes for those who have already acquired a knowledge of the use of tools. Classes will be formed in mechanism, engineering, drawing, applied mechanics, theory of structures and the application of higher mathematics to engineering. The professor means to found a first-class school for civil and mechanical engineering, and evidently intends to leave no stone unturned to accomplish this object, as well as to teach candidates for the University examinations.

Mr. Garnett will lecture on heat in the Cavendish Laboratory on Mondays, Wednesdays, and Fridays, this term.

OXFORD.—In a congregation held on the afternoon of February 3, Mr. Vernon Harcourt's amendment to the form of statute, respecting degrees in Natural Science came on for discussion. It will be remembered that the preamble of the statute alone remains, enacting that it is expedient for the University to grant degrees in Natural Science. When it appeared by counsel's opinion that the new degree in Natural Science would not confer on the graduate the privileges of a member of convocation, all the clauses of the proposed statute were rejected after a close division last term. Mr. Harcourt's proposal was to insert a clause in the statute to the effect that "every person who shall have been admitted to the degree of Natural Science shall also be admitted to the degree of Master of Arts." This proposal was defeated by a large majority, 27 voting for it, and 110 against it.

The examiners for the Burdett-Coutts geological scholarship have given notice that the examination will commence on Monday, February 16, at 10 a.m. The scholarship is tenable for two years, and is open to all members of the University who have passed all the necessary examinations for the B.A. degree, and shall not have exceeded their twenty-seventh term. The examiners are Prof. Prestwich, Dr. Odling, and Mr. Hatchett Jackson.

There will be an election to at least one junior studentship in natural science at Christ Church, on February 21. Candidates must not have exceeded the age of twenty on January 1, 1880. Papers will be set in chemistry, biology, and physics, but no candidate will be allowed to offer himself in more than two of these subjects. The examination begins on February 11.

The composition of the governing body of the French University has been the occasion of protracted and violent debates in the French Senate. It was only by a few votes that M. Ferry obtained its secularisation and expelled all ministers of every denomination.

The Geneva University numbers now 525 students and assistants, 134 more than last year, of whom 106 are in the faculty of science, 208 in that of literature, 35 in philosophy, 15 in theology, 54 in law, and 107 in medicine; 125 are Swiss, strangers to Geneva, and 200 foreigners.

We learn from a paper just published in the *Journal* of the Russian Ministry of Public Instruction that the number of scholars in all Russian colleges (gymnasia) reached 53,072 in 1878. But the figures as to the number of scholars who have terminated their studies in colleges are very unsatisfactory. Out of 57,917 scholars who entered the colleges during six years (1872 to 1877), only 6,511, *i.e.*, 2·5 per cent. terminated their studies, 51,406 having left the colleges without having received attestations of maturity. In "Real" schools, where the whole education is based on the study of natural science instead of that of language, the percentage is far more satisfactory.

SCIENTIFIC SERIALS

Zeitschrift für wissenschaftliche Zoologie, 33 Bd. 3 Heft, December, 1879, contains:—Conrad Keller, studies on the organisation and development of *Chalinula fertilis*, pl. 18 to 20.—Dr. G. Haller, contributions towards a knowledge of the *Læmodipodes filiformes*; commencing with a very careful and detailed account of the anatomical details to be met with in that group, it proceeds to an account of the life-history of the species, with a paragraph on their mimicry, under the heading "Darwinia": among the epizootic animals described is a very curious new species of Podophrya, with a long tapering and transversely striated stalk, and possessing a nucleus, with nucleolus, and to this follows the systematic portion, in which several new species of Proto, Caprella, and Podalirius are described and figured, pl. 21 to 23.—Olga Metschnikoff, on the morphology of the pelvic and shoulder girdles in cartilaginous fishes, pl. 25 and 26.—A. Gruber, on new infusoria, describes a number of new genera of fresh water infusoria.—Prof. Selenka, on a siliceous sponge with an octoradiate structure, and on the development of sponge-offsets, pl. 27 and 28.

Nyt Magazin for Naturvidenskaberne, 25de Binds, 2det Hefte, 1879.—D. C. Danielssen and J. Koren, the echinoderms of the Norwegian North Sea Expedition. Several very remarkable new genera and species belonging to the Holothuriadæ are described and excellently figured in this part.—Leonard Stejneger, contributions towards the Western ornithological fauna.

Journal de Physique, January.—On the thermal laws of the electric spark in gases, by Prof. Villari.—Projection of images formed between two plane mirrors, by Prof. Bibart.—On the compressibility of air and carbonic acid at 100°, according to M. Regnault's experiments, by M. Bouty.—Chloride of lime battery, by M. Niaudet.—Photometric researches on coloured flames, by M. Gouy.—New producer of electricity based on capillarity, by M. Debrun.

Reale Istituto Lombardo di Scienze e Lettere, Rendiconti, vol. xii., fasc. xx.—On the structure of the peripheric and central medullated nerve fibres, by Prof. Golgi.—On the temperature and humidity of the air, and the formation of dew in the neighbourhood of great lakes, by Prof. Cantoni.—On the conditions of most suitable form and exposure of evaporimeters, by the same.

SOCIETIES AND ACADEMIES

LONDON

Royal Society, January 15.—"Results of an Inquiry into the Periodicity of Rainfall." By G. M. Whipple.